Review Summary of FLDWAV Computer Program, Version 1.0.0

FLDWAV, Version 1.0.0, released by the NWS, is a generalized flood routing program with the capability to model flows through a single stream or a system of interconnected waterways. It replaces the NWS programs DAMBRK and DWOPER. Similar to FLDWAV, DAMBRK, released in 1988, and DWOPER, released in 1984, are generalized flood routing models. While DAMBRK has the ability to analyze the flow of a single stream, DWOPER has the additional capability to model flows through a system of interconnected waterways. Effective Flood Insurance Studies (FISs) have been prepared using the DAMBRK and DWOPER programs and they are included in the Federal Emergency Management Agency's list titled, "Numerical Models Accepted by FEMA for NFIP Use." During our review, sensitivity tests were conducted on FLDWAV and DAMBRK. The tests indicated that the results of FLDWAV analysis compare well with those of DAMBRK. The results of the tests and further review of the capabilities of FLDWAV indicated that, similar to DAMBRK, FLDWAV is also suitable for the hydraulic analysis of floodplains unobstructed by control structures and, therefore, can be included in FEMA's accepted models list. Since, the analysis of dam-breach floods is not included in the FISs, the breach-modeling feature of FLDWAV will not be used to create FIS models.

The theoretical basis, modeling capabilities, and limitations of the FLDWAV computer program are briefly summarized in this attachment. In addition, a comparison of the results of FLDWAV and DAMBRK analyses are included.

Theoretical Basis of NWS FLDWAV

The complete one-dimensional St. Venant equations of unsteady flow and an assortment of external and internal boundary conditions form the basis for the floodplains simulated by FLDWAV.

Model Capabilities

The FLDWAV computer program is designed to analyze large flood events usually caused by breach of a dam and to predict the movement of a large flood wave in the real-time forecasting done by the NWS River Forecasting System.

FLDWAV has the capability to model flows with the following characteristics:

Flow system: single channel or dendritic systems, straight or meandering channels;

Flow regime: free surface flows in subcritical, supercritical, and mixed flow regimes, and pressurized conduit flows;

Fluid type: Newtonian (clear water) fluids and analysis of non-Newtonian (mud/ debris flows) will be included in the next release expected by December 1999;

Off-channel storage:
has the capability to define ineffective flow areas in cross sections, this will be use to model ineffective flow areas;

Flow Controls: time dependent dam breaches;
time dependent gate controls;
flow over spillways;
flow through waterfalls and short rapids;
pressure and weir flow of bridges and
breaches of bridge embankments;
low flows through bridge embankments; and
multiple levee over-toppings and breaches.

Other Useful Features

FLDWAV has the capacity to interpolate cross sections. FLDWAV can also read rating curve data as input. This feature gives FLDWAV the capability to use the stage-discharge relationships of control structures developed by other models or obtained through monitoring studies.

FLDWAV can also use an optimization procedure to determine the Manning's roughness coefficients necessary to calibrate to observed high-water marks (automatic calibration).

Model limitations

Culvert flows:

FLDWAV does not have a culvert analysis routine. In its current form, FLDWAV bridge analysis or pressurized flow analysis can be used to model culvert flows. However, culvert flows are more accurately modeled using the Federal Highways Nomographs based on lab testing results. The results of the FLDWAV model would be enhanced if the culvert flow characteristics are analyzed externally (using FHWA methods) and imported as a rating curve. The NWS plans to include a culvert analysis routine in the next update of this program.

Flow Through Storm Sewers:

The current version of FLDWAV does not have the capability to model storm sewer junctions and energy losses associated with manholes.

Floodway Modeling:

The current version of FLDWAV cannot define floodway stations based on equal conveyance reduction criteria.

Technical Support

Technical support for FLDWAV application problems is available through the NWS River Mechanics web page at the following (internet) address: Hsp.nws.noaa.gov/oh/hrl/rvrmech/rvrmain.htm

FLDWAV and the NFIP

In the NFIP, the 10-, 50-, 100-, and 500-year floodplains and floodway boundaries of riverine flooding sources are generally determined by using hydraulic computer programs capable of analyzing flows of streams and control structures located in floodplains. Bridges and culverts are the control structures frequently situated within floodplains. The flood elevations defined on a FIS's Flood Profiles can be read to an accuracy of 0.1 foot. In addition, FEMA defines floodways only for streams studied in detail for FISs. The floodways are generally defined based on equal conveyance reduction criteria.

The current version of FLDWAV can analyze general riverine floodplains (natural floods). Similar to DAMBRK, the features built into FLDWAV make it suitable to analyze large flows generally associated with dam breach events.

The following limitations of FLDWAV should be considered before using it to analyze floodplains for the NFIP.

- Definition of cross section geometry

  The geometry of the channel and the overbank are represented in FLDWAV by cross sections. The cross section geometry is defined by the relationship between the top width and its corresponding elevation. This method of defining the channel geometry is more suited to input data measured from a topographic map. The cross sections used in FIS models are generally more accurately determined by ground surveys and usually defined as a horizontal distance and its corresponding elevation. The accuracy obtained by a ground survey may be lost while translating it to the format used in FLDWAV (top widths and corresponding elevations.)

- Modeling flows through bridges and culverts

  Care should be taken when analyzing floodplains with bridges and culverts. Similar to DAMBRK, FLDWAV can also analyze the flows, (pressure flow, pressure and weir flow) bridges, and long pipes. However, the present review did not include sensitivity tests to check results of FLDWAV bridge analysis with those of other accepted models. Until FLDWAV bridge analysis is expanded to analyze flows through culverts, it is recommended that, similar to DAMBRK, the use of FLDWAV in the NFIP will be limited to floodplains unobstructed by bridges and culverts. However, the use of FLDWAV can be extended for floodplains with bridges and culverts if the discharge characteristics of control structures were developed using NFIP accepted methods and imported into the FLDWAV model as a rating curve.

Sensitivity Tests

The DAMBRK modeling of approximately 1.26 miles of the Black River used in the Village of Dexter, New York, FIS was converted to a FLDWAV model. The flood elevations computed by these two analyses matched within 0.05 foot, as demonstrated below in Table 1, "Comparison of FLDWAV and DAMBRK Flood Elevations for the Black River."

This sensitivity test indicates that FLDWAV can compute flood elevations comparable to those computed by DAMBRK.

Table 1 - Comparison of FLDWAV and DAMBRK Flood Elevations for the Black River

Cross section distance from dam in miles	Flood elevation (Feet NGVD)		Difference In feet
	FLDWAV	DAMBRK	
0.000	265.05	265.05	0.00
0.010	254.78	254.79	-0.01
0.126	253.84	253.84	0.00
0.296	252.38	252.38	0.00
0.306	252.28	252.28	0.00
0.536	247.85	247.89	-0.04
0.596	246.52	246.57	-0.05
0.646	247.65	247.67	-0.02
0.846	247.31	247.31	0.00
1.066	242.72	242.68	+0.04
1.226	235.00	235.97	-0.03

Recommendations: Use of FLDWAV to Revise Effective DAMBRK FIS Models

The following guidelines are recommended for the use of FLDWAV to revise effective DAMBRK analyses:

- If only a portion of the floodplain is revised, for purposes of convenience (to have one FIS hydraulic model instead of two), DAMBRK should be used for the analysis.
- If the entire floodplain is revised, FLDWAV should be used to create the new model.
- If a new analysis is conducted to define flood elevations currently analyzed by approximate methods, FLDWAV should be used.
- Areas currently analyzed by approximate methods can be revised on the basis of existing DAMBRK analyses.